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Evaluation of Muskellunge and Tiger Muskellunge Stocking Program

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EVALUATION OF MUSKELLUNGE AND TIGER MUSKELLUNGE STOCKING PROGRAM

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Study 101. Evaluation of muskellunge and tiger muskellunge stocking program.

Job 101.1 Size-specific survival of muskellunge and tiger muskellunge.

OBJECTIVE: To compare survival of various sizes of muskellunge and tiger muskellunge stocked in Illinois impoundments.

INTRODUCTION: Stocking is a popular management tool to provide sport fishing opportunities and to supplement existing sport fish populations (Keith 1986). The success of fish stocking programs is largely dependant upon the ensuing survival rates. Stockings of esocid fingerlings have displayed extremely variable survival rates (Wahl and Stein 1989; Stein et al 1981; Johnson 1982). The sizes to which esocids must be reared to attain acceptable rates of survival is largely dependant upon system specific characteristics such as forage species abundance and size, predator density and size distribution, and thermal regime. Survival of esocid fingerlings in impoundments has been shown to be largely dependant upon predation by resident largemouth bass (Stein et al. 1981) and the composition and abundance of forage fishes (Wahl and Stein 1988). Sizes to which esocids must be reared will vary according to the predator population and forage base of a specific system. The success of various size stockings need to be correlated with these factors to develop guidelines for impoundment stockings. These results will be used to improve and test a bioeconomic model developed by Wahl and Stein (1990) to compare the factors influencing survival of various sizes of esocids as a function of cost of rearing. In this job, we evaluate the relative survival of 4, 8 and 10 inch muskellunge and tiger muskellunge with impoundment stockings, and assess the effects of predator populations and prey sources on survival. These data will be used to help develop guidelines for future esocid stockings in Illinois.

METHODS: Pierce lake (Winnebago Co.) was stocked with 6, 8 and 10 inch muskellunge and Paris-Twin Lake (Edgar Co.) was stocked with 4, 8 and 10 inch tiger muskellunge. Numbers of fish stocked varied by size and species of esocid (Table 1). All fish were reared intensively at the Jake Wolf Memorial fish hatchery in Manito, Illinois, by the Illinois Department of Conservation. Unique fin clips were given to each size group of fish. A sample of each esocid size group was measured (nearest mm) and weighed (nearest g) prior to stocking (Table 1). Fish were tempered to within 5 C of lake temperature before stocking to avoid thermally stressing the fish (Mather and Wahl 1989). A sub-sample of each stocked group was held in three predator-free cages (N=15/cage) for 48 hours to monitor mortality associated with stress due to transport and stocking. Temperature and dissolved oxygen measurements were recorded on each sampling date in order to determine their influence on survival rates.

Predation by largemouth bass was determined by examining contents of largemouth bass stomachs with clear acrylic tubes (Van Den Avyle and Roussel 1980), and extracting any esocids. Largemouth bass were sampled by electrofishing the entire perimeter of each lake the first three nights after stocking, then once a week thereafter until no more esocids were collected from largemouth bass. Largemouth bass were marked to determine population estimates. The number of esocids collected from largemouth bass stomachs on each date was combined with largemouth bass population estimates to compute the total number of each esocid group eaten daily (Wahl and Stein 1989). These values were then summed to compute total predatory mortality.

Population estimates and catch-per-unit-effort for muskellunge and tiger muskellunge were computed in the fall and spring to determine survival rates. The entire perimeter of each lake was sampled at weekly intervals by electrofishing. All esocids collected were given a caudal fin clip for mark-recapture population estimates of various sizes of stocked esocids.

RESULTS: Survival rates of stocked fish through fall revealed no survival for the 4 and 8 inch tiger muskellunge in Paris Lake, and very low survival through fall of 6 and 8 inch muskellunge in Pierce lake (Table 2). Four inch tiger muskellunge were not collected beyond the second week after stocking, and 8 inch fish were not collected beyond the fifth week (Table 3). Fall sampling collections in Pierce Lake showed 6 and 8 inch muskellunge to be present, although catch-per-unit-effort (CPUE) values were very low (Table 4). Population estimates for 8 inch muskellunge were low (4% survival; Table 2), whereas insufficient numbers of 6 inch muskellunge were collected to compute a population estimate. In contrast to smaller size groups, survival of 10 inch tiger muskellunge (23%) and muskellunge (12%) through fall was much higher (Table 2) and allowed for mark-recapture population estimates. Survival of 10 inch muskellunge was three times higher than for 8 inch fish, whereas 10 inch tiger muskellunge were the only surviving size class through fall.

Numbers of esocids recovered from largemouth bass stomachs combined with largemouth bass population estimates (Table 5) revealed high predatory mortality on all sizes of tiger muskellunge stocked in Paris Lake (Table 6), but low predatory mortality of muskellunge in Pierce Lake. Differences between muskellunge and tiger muskellunge may be due to differences among taxa or to differences among lakes. Population estimates of largemouth bass were substantially higher in Paris-Twin Lake than in Pierce Lake and is most likely responsible for observed differences. For both taxa, intermediate (8 inch) fish suffered higher losses to predation than other size groups, whereas the largest size groups (10 inch) had the lowest losses to predation.

No mortality was observed in cages for up to 48 hours following all six stockings, indicating no effect of transport or stocking stress on survival rates. In all stockings, esocids were acclimated to within 5 C of lake temperatures prior to stocking.

Spring electrofishing collections on Paris Lake again revealed no 4 or 8 inch tiger muskellunge survival and few 10 inch fish, suggesting high overwinter mortality on this remaining size group. Spring sampling of muskellunge on Pierce Lake found substantially higher numbers of 10 inch fish (N=49, population estimate), with only two 6 and one 8 inch fish sampled.

RECOMMENDATIONS: Stockings of 4, 8 and 10 inch muskellunge and tiger muskellunge should be repeated in 1991 in order to further evaluate the effects of size at stocking on survival and growth rates of esocids. Results from 1990 stockings indicate that survival of fish less than 10 inches is poor, but additional stockings of small size groups should be evaluated in the next segment. In 1991, individual lakes should be switched with those used in Job 101.2 in order to eliminate individual lake effects. In addition, sampling of fish stocked in 1990 should be continued in order to monitor the effect of size at stocking on survival and growth rates through the second year. In subsequent segments, we will also begin to incorporate data collected in this job into the esocid bioeconomic model. Simulations from this improved model will be useful in determining trade-offs between costs of rearing and size at stocking for individual impoundment characteristics.

Job 101.2 <u>Effect of rearing technique on esocid survival.</u>

OBJECTIVE: To compare survival of minnow and pellet reared muskellunge and tiger muskellunge in impoundments.

INTRODUCTION: In addition to size at stocking, another factor which hatcheries can control which may potentially impact stocking success is rearing method. Extensive rearing of esocid fingerlings on minnows has been utilized for most stocking programs, however intensive rearing on pellets has been found to be a less expensive alternative (Klingbiel 1986). However, the survival and behavioral characteristics of esocids reared on minnows and dry diets should be evaluated before the implementation of large-scale use of artificial diets (Hanson et al 1986; Carline et al 1986). Differential susceptibility to predation and conversion to available prey sources may greatly influence the survival and growth rates of fingerling esocids reared by different methods. In this job, we compare survival and growth rates of minnow and pellet reared muskellunge and tiger muskellunge and evaluate potential mechanisms causing observed differences in growth and survival.

METHODS: Equal numbers and similar sizes (200 mm) of minnow and pellet reared muskellunge and tiger muskellunge were stocked simultaneously into reservoirs in Illinois (Table 1). These esocids are of a size that typically show intermediate survival, and have the potential to be greatly affected by rearing method. Muskellunge were stocked in Lake George (Rock Island Co.) and tiger muskellunge in Paradise Lake (Coles Co.).

All fish were reared intensively at the Jake Wolf Memorial fish hatchery in Manito, Illinois by the Illinois Department of Conservation. Pellet reared esocids were marked with oxytetracycline, whereas minnow reared fish were not. Oxytetracycline is incorporated into calcium deposits and will fluoresce under ultraviolet light (Wahl and Stein 1987). Incorporating oxytetracycline into the food allowed esocids recovered from largemouth bass stomachs to be distinguished by rearing method. Minnow and pellet reared fish of both species were graded to match sizes. Minnow and pellet reared esocids received unique fin clips prior to stocking which has been found to be an effective method of marking stocked esocids (McNeil and Crossman 1971). A sample of each esocid rearing type was measured (nearest mm) and weighed (nearest g) prior to stocking (Table 1). Fish were tempered to within 5 C of lake temperature before stocking to avoid thermally stressing the fish (Mather and Wahl 1989). A sub-sample of each stocked group was held in three predator-free cages (N=15/cage) for 48 hours to monitor mortality associated with stress due to transport and stocking.

Susceptibility to predation by largemouth bass was determined as in Job 101.1. The number of minnow and pellet reared fish collected from largemouth bass stomachs on each date was combined with largemouth bass population estimates to compute the total number of each rearing type eaten daily. These values were then summed to compute total predatory mortality. Temperature and dissolved oxygen measurements were recorded on each sampling date in order to determine their influence on survival rates.

Population estimates and catch-per-unit-effort for minnow and pellet reared muskellunge and tiger muskellunge were computed in the fall and spring to determine survival rates. The entire perimeter of each lake was sampled at weekly intervals by electrofishing. All esocids collected were given a caudal fin clip for mark-recapture population estimates of minnow and pellet reared fish.

RESULTS: Number of esocids recovered from largemouth bass stomachs indicated higher susceptibility to predation for pellet reared than for minnow reared tiger muskellunge and muskellunge. In Paradise Lake, more pellet reared (N=26) than minnow reared (N=11) tiger muskellunge were recovered from largemouth bass stomachs (chi-square, $p < .025$). Similarly, more pellet reared (N=30) than minnow reared (N=17) muskellunge were recovered from largemouth bass stomachs in Lake George (chi-square, $p < .10$). When numbers of tiger muskellunge (Figure 1) and muskellunge (Figure 2) collected from largemouth bass stomachs on each date were combined with largemouth bass population estimates (Table 5), estimated predation on esocids was nearly three times higher on pellet reared than minnow reared tiger muskellunge, and over twice as high on pellet than minnow reared muskellunge (Table 6). These results suggest that rearing technique has a strong influence on relative predation rates on minnow and pellet reared esocids in impoundments and may thus be an important factor affecting survival.

No significant mortality was observed in cages for up to 48 hours following either stocking, indicating no effect of transport or stocking stress on survival rates.

As predicted by losses to largemouth bass predation, fall population estimates showed survival of minnow reared tiger muskellunge to be over four times higher (17%) than for pellet reared fish (4% ; Table 2). Separate survival estimates of minnow and pellet reared tiger muskellunge were obtained as the percentage of each in the total catch, because recaptures of pellet fish were too low to compute an independent population estimate. Similarly, catch-per-unit-effort (CPUE) values remained substantially higher through fall and spring (Table 7) for minnow reared tiger muskellunge in Paradise Lake. Catch rates were low for muskellunge in Lake George during fall and none were sampled past the second week after stocking (Table 8). However, spring electrofishing collections have produced more minnow (N=4) than pellet reared (N=2) muskellunge. Insufficient numbers of muskellunge have been captured in Lake George to permit estimates of survival during fall or spring. Numbers of largemouth bass in Lake George as determined by mark-recapture population estimates (Table 5) were almost twice as high as those in Paradise Lake, and appear to be at least partially responsible for the apparent low survival of muskellunge in this lake.

RECOMMENDATIONS: Stockings of minnow and pellet reared muskellunge and tiger muskellunge should be replicated in 1991. Results from 1990 stockings suggest rearing method may play an important role in esocid survival in impoundments. In 1991, lakes will be switched with those used in Job 101.1 in order to eliminate individual lake effects. Sampling of fish stocked in 1990 will be continued in order to monitor the effect of rearing method on survival and growth rates through the second year.

Job 101.3 <u>Laboratory and pond experiments.</u>

OBJECTIVE: To evaluate growth and survival rates of various sizes, minnow versus pellet reared, and genetic stocks of esocids in laboratory and pond experiments.

INTRODUCTION: Pond and laboratory experiments have been used often to determine the mechanisms that cause differences observed in field studies (Wahl and Stein 1989, Werner et al. 1983, Savino and Stein 1982). In comparing survival of muskellunge, tiger muskellunge and northern pike, Wahl and Stein (1989) used both experimental ponds and laboratory pools to compare vulnerability of esocids to largemouth bass predation.

These experiments were extremely useful in evaluating mechanisms of differential survival. Differences in susceptibility to predation among pellet and forage reared esocids may have dramatic influences on survival. In this job, we employ the use of experimental ponds and laboratory pools to examine the susceptibility to largemouth bass predation and habitat use of minnow and pellet reared muskellunge and tiger muskellunge.

METHODS: Susceptibility of intensively reared minnow and pellet fed muskellunge and tiger muskellunge to predation by largemouth bass was examined in two sets of pond (.04 ha) experiments. Muskellunge and tiger muskellunge reared intensively at the Jake Wolf hatchery were transferred to the Sam Parr Biological Station in Kinmundy, Illinois. For each taxa, half of similar sized fish were reared on pellets and the other half were reared on minnows for at least four weeks prior to stocking. Pellet reared fish were marked with oxytetracycline and minnow and pellet reared fish received distinguishing fin clips. Each experiment was conducted using 6 treatment and 4 control ponds. Pellet (N=25) and minnow (N=25) reared fish of a single taxa were added to each of 10 ponds. Treatment ponds also contained largemouth bass (N=6) and were used to examine relative predation rates on minnow and pellet reared fish. Control ponds did not contain largemouth bass and were used to monitor natural mortality. Temperature, dissolved oxygen and secchi depth were monitored daily after introduction of esocids. All ponds were seined on days 1, 3, 5 and 9 after stocking and esocids were extracted from largemouth bass stomachs to compare losses to predation between rearing types. Numbers of minnow and pellet reared esocids seined from each pond on each sample date will be used to evaluate survival through time. All ponds were drained on day 9 to determine survival rates of esocids.

Susceptibility to largemouth bass predation and habitat utilization of minnow and pellet reared muskellunge and tiger muskellunge were examined in laboratory pool experiments at the Kaskaskia Biological Station. A freeze-brand mark was used to distinguish between minnow and pellet reared fish of identical size obtained from the Jake Wolf Hatchery. Each experiment consisted of two minnow and two pellet reared fish of a single species placed in a 2.5 m laboratory pool containing simulated vegetation in one half of the pool (Wahl and Stein 1989). Recordings were made every 2 minutes over a 30 minute period on habitat utilization and position in the water column by esocids. A single largemouth bass (N = 7 individuals) was then released into the pool. Number of strikes per capture by rearing type, distance followed, and area of the pool where strikes occurred were recorded. The experiment terminated when a single fish was captured. Relative predation and habitat utilization of minnow and pellet reared fish was examined from these data.

RESULTS: Pond experiments with tiger muskellunge (mean length = 184 mm, mean weight = 28.4 g for pellet; mean length = 178 mm, mean weight = 28.6 g for minnow) showed survival to be marginally higher for minnow reared fish than for pellet reared fish based on seining during the experiments. Of the six treatment ponds with largemouth bass, survival was higher for minnow reared fish than for pellet reared fish in four of the ponds and similar in one of the ponds. The single remaining pond showed higher survival for pellet reared tiger muskellunge. Pond experiments with muskellunge (mean length = 183 mm, mean weight = 22.2 g for pellet; mean length = 185 mm, mean weight = 22.1 g for minnow) showed no difference in survival between minnow and pellet reared fish.

Comparison of esocids recovered from largemouth bass stomachs showed similar patterns as seine data. More pellet (N=37) than minnow (N=23) reared tiger muskellunge were eaten by largemouth bass (chi-square, $p < .10$) in all ponds combined. In contrast, more minnow (N=20) than pellet (N=12) reared muskellunge were eaten by largemouth bass (chi square, $p < .30$) in all ponds combined.

We also completed a series of laboratory pool experiments with tiger muskellunge (N=53) and muskellunge (N=32). Evaluation of susceptibility to largemouth bass predation revealed captures of minnow and pellet reared fish to be similar for tiger muskellunge (25 pellet, 24 minnow; chi-square, $p > .85$), and muskellunge (16 pellet, 12 minnow; chi-square, $p > .50$). In addition, no differences were observed in habitat selection or water column positioning for minnow and pellet reared fish of either taxa (Table 9).

RECOMMENDATIONS: Additional analysis of pond data should be conducted. Survival data at draining for tiger muskellunge and muskellunge will be compared by t-test to determine differential vulnerability of pellet and minnow reared esocids. In addition, total number of esocids eaten will be estimated by summing numbers of esocids per largemouth bass stomach on each sampling date as in the reservoir experiments (see Job 101.2). Pond experiments with tiger muskellunge should be repeated in 1991 to increase the number of replicates. Additional analysis of pool experiments should also be conducted.

In the next segment, we will also begin laboratory experiments to compare growth, consumption rates and metabolic rates of different genetic stocks of muskellunge (see Job 101.5 for additional discussion).

Job 101.4 Growth and food habits of muskellunge and tiger muskellunge.

OBJECTIVE: To determine the effect of stocking size and rearing technique on growth rates and food habits of esocids.

INTRODUCTION: The relative success of muskellunge and tiger muskellunge in utilizing prey resources in impoundments after introduction can play a large role in the overall success of a particular stocking. Differences in conversion to available prey sources in the field can significantly influence survival and growth rates (Wahl and Stein 1988 ; Tomcko et al 1984). These differences are primarily the result of foraging efficiency of the fish and characteristics of the individual prey species. Gillen et al. (1981) examined the effect of the diet history (minnow vs pellet fed) of tiger muskellunge on foraging success, and found longer capture times and higher strikes per capture by pellet reared fish. These differences may be attributable to behavioral differences between the two rearing methods. The availability of adequate sizes of forage fish to various sizes of stocked esocids can also influence survival. In this job, we examine the effect of rearing method and size at stocking on the prey utilization and growth rates of muskellunge and tiger muskellunge in impoundments.

METHODS: Each group of esocids stocked were sub-sampled for length (nearest mm) and weight (nearest g) prior to stocking (Table 1). Esocids were then collected at bi-weekly intervals by electrofishing the entire perimeter of each impoundment. Esocids were measured and weighed at each collection date to determine relative growth rates of minnow and pellet reared fish and of various sizes of stocked esocids. Stomach contents of all esocids collected were removed by stomach flushing (Foster 1977) to determine food habits and to examine differences in diet conversion between minnow and pellet reared esocids.

Five stations were seined with 75 foot hauls at bi-weekly intervals to determine inshore species composition, densities and size distribution of prey fishes available in each impoundment. Prey were identified to species and counted. These data will be used to evaluate the role of forage base in affecting growth and survival of stocked esocids.

RESULTS: Growth and food habits data were not available for 4 inch tiger muskellunge because of their absence from sampling collections in Paris-Twin Lake. Eight inch fish showed little increase in size through week six (Table 10), and insufficient food habits data was available for these size tiger muskellunge. Mean lengths and weights through fall of 10 inch tiger muskellunge in Paris Lake showed a small increase in length, but fish appear to have lost weight throughout this period (Table 10) and into the spring. Seining collections for available prey consistently revealed a low density of adequate sized prey species and a composition dominated mainly by bluegill. Bluegill have been found to be a sub-optimal forage for tiger muskellunge in previous reservoir studies (Wahl and Stein 1988). Analysis of food habits indicates few fish were capturing prey before late fall and bluegill were the dominant prey item of those with food (Table 11). As suggested by low survival rates, insufficient weight gain may have been achieved to allow for overwinter survival of these size tiger muskellunge.

Muskellunge in Pierce Lake showed negligible growth for the 8 and 10 inch size groups through spring (Table 12), with only small increases in length. Muskellunge condition factors were also low with virtually no gains in weight. In contrast, six inch muskellunge displayed substantial growth in both length and weight through the first 10 weeks following stocking (Table 12). However, inadequate samples were obtained to assess growth rates after this time. Seining collections showed prey species to be numerous and varied, with shiner species in highest abundance. Food habits analysis of muskellunge during fall and spring revealed similar utilization of a variety of prey species (Table 13).

Tiger muskellunge in Paradise Lake showed extremely large increases in length and weight through fall and spring, with minnow reared fish growing consistently faster than pellet reared fish (Table 14). These growth patterns have been maintained through week 34, after which time only minnow reared fish have been collected. Seine samples in Paradise Lake indicate a prey base dominated by gizzard shad and bluegill. Supplementary electrofishing samples have shown gizzard shad to be exceedingly abundant, with large numbers of appropriately sized gizzard shad available as forage. Analysis of food habits of tiger muskellunge in Paradise Lake show gizzard shad to be the dominant prey item (Table 15), representing approximately 95% of all identified food items. The high density of gizzard shad in Paradise Lake appears to have had a strong impact on the fast growth of tiger muskellunge compared to other lakes without gizzard shad. No differences in prey conversion or prey species utilization were observed between minnow and pellet reared tiger muskellunge (Table 15), although sample sizes of pellet fish were low.

Muskellunge sample sizes in Lake George were extremely low and made growth evaluations difficult. Based on these limited data, it appears that growth rates of minnow and pellet reared muskellunge were similar in Lake George (Table 16), with both minnow and pellet reared fish achieving limited growth in length and weight through fall and spring. Seine collections have shown bluegill to be the most dominant prey item available. However, food habits suggest that bluegill were not utilized in proportion to their occurrence, with low numbers observed in esocid diets (Table 17).

RECOMMENDATIONS: All esocids stocked in 1990 should continue to be sampled by electrofishing at monthly intervals to monitor growth and food habits. Seine collections will also continue on all four study lakes in 1991 to evaluate composition, density, and size distribution of available prey. In 1991, we will also monitor growth and food habits of tiger muskellunge and muskellunge stocked in Jobs 101.1 and 101.2.

JOB 101.5. <u>Assessment of different genetic stocks of muskellunge.</u>

OBJECTIVE: To identify different genetic stocks of muskellunge and to evaluate their performance characteristics for stocking in Illinois impoundments.

INTRODUCTION: Muskellunge have been stocked outside of their native range in many parts of North America, including Illinois. Preliminary work has shown that genetic techniques will be useful for identification of geographically distinct stocks. Each stock has evolved under different ecological conditions, and is therefore expected to have different performance characteristics. Growth rates, maximum size, longevity, and survival are among the traits that will affect an individual stock's value to Illinois fisheries. The purpose of this job is to use genetic techniques to identify different genetic stocks of muskellunge and then to evaluate their performance characteristics for stocking in Illinois impoundments.

METHODS AND RESULTS:

Allozyme analysis

Muskellunge samples were received from several state agencies in the fall of 1990. Additional samples will be obtained during summer, 1991. Samples obtained in 1990 have been subject to vertical starch gel electrophoresis to measure genetic variation at loci known to be polymorphic in muskellunge, and at several loci that had not been previously evaluated in this species.

Nine loci known to exhibit polymorphism in muskellunge were evaluated (Table 18). No variation was detected at the EST-1, EST-2, and IDHP-2 loci. Two loci (IDHP-1 and AAT-M) are polymorphic, but most likely represent a pair of duplicated loci sharing common alleles. Resolution at these loci was insufficient to quantify individual band staining intensities; therefore, the allele frequencies are not given.

The results of the allozyme analyses are qualitatively similar to those obtained in a preliminary study conducted by Koppelman and Philipp (1986). 6-PGDH was polymorphic in all populations. Two loci, GPI-B and LDH-C, show evidence of geographic differences in allele frequencies. Populations obtained from Minnesota were fixed for one allele at each of these loci. A rare allele at the XDH-1 locus was found in the Spirit Lake, Iowa and Little Falls, Minnesota samples. Rare alleles detected at the EST-1, EST-2, and IDHP-2 loci in the preliminary study (Koppelman and Philipp 1986) were not found in the current study; however, we have not yet evaluated fish from the St. Lawrence R., in which the rare alleles were prevalent.

In addition to expanding the geographic extent of previous allozyme samples, we also screened muskellunge tissue for variation at 9 additional loci. A total of 66 loci have now been evaluated. Among the 9 newly evaluated loci, no additional polymorphisms were detected.

Allozymes detected in fin tissue are useful as marks or tags in performance evaluations. Non-lethal fin clips can be used to determine experimental treatment group in long-term experiments in ponds or in natural systems. The Gpi-B locus is polymorphic and easily detected in fin tissue. This locus may be useful for experiments using populations differing in GPI-B allele frequencies, and may also be useful for producing genetically tagged stocks for performance evaluations in Illinois.

Mitochondrial DNA

Mitochondrial DNA (mtDNA) is also useful for measuring genetic variability. This molecule can reveal additional genetic variation not detected with allozymes because it evolves more rapidly than structural nuclear genes. Because adult muskellunge are a valuable resource, it is not desirable to use destructive sampling techniques commonly used to evaluate mtDNA restriction fragment length polymorphisms (RFLP's). Much current mtDNA work with gamefish utilizes liver tissue to isolate large quantities of mtDNA, which is visualized with ethidium bromide staining. However, established techniques that use hybridization with a ^{32}P-labelled mtDNA probe will allow the same information to be recovered from small, non-lethal tissue samples. This technique will allow us to evaluate genetic variation of both wild and hatchery stocks of muskellunge from throughout its distribution.

Procedures for mtDNA RFLP analysis involve isolation of genomic DNA (nuclear and mitochondrial) from muskellunge tissue and cutting with restriction enzymes. The DNA is then run on an agarose gel and dried. Labelled mtDNA probe is then hybridized to the dry gel and visualized by autoradiography. We have successfully performed this procedure with small (<0.2 g) samples of muscle tissue, and are currently evaluating its use with fin tissue. Both tissues will allow non-lethal sampling of wild populations of muskellunge.

Evaluation of mtDNA RFLP (from muscle tissue) is in progress for samples obtained from eleven hatchery sources. In addition, samples of fin tissue from adult muskellunge were received from the Wisconsin DNR and Ohio DNR. Analysis of these samples, which will determine the utility of this technique for fin tissue samples is also in progress.

RECOMMENDATIONS:

Additional samples should be obtained for analysis by gel electrophoresis. In particular, populations from the St. Lawrence River drainage and from Northern Wisconsin have not yet been evaluated. Analysis of mtDNA RFLP needs to be completed for all stocks being considered. These data, along with allozyme data will allow identification of distinct muskellunge stocks.

During the next segment, we will begin laboratory evaluation of performance characteristics of the muskellunge stocks identified through our genetic work. Muskellunge will be obtained from several state hatchery systems throughout its range. We will compare growth and metabolic rates of these stocks as a function of water temperature (see Job 101.3). These laboratory experiments will provide preliminary data on how different muskellunge stocks might survive and grow in the thermal regimes present in Illinois. Ultimately, these results can be used to guide additional pond and reservoir studies of different muskellunge stocks in Illinois.

Job 101.6. Analysis and reporting.

OBJECTIVE: To prepare annual and final reports which develop management guidelines for stocking esocids in Illinois impoundments.

RESULTS AND RECOMMENDATIONS: Relevant data were analyzed and reported in individual jobs of this report (see Job 101.1 - 101.5).

References:

Carline, R.F., R.A. Stein, L.M. Riley. 1986. Effects of size at stocking, season, largemouth bass predation, and forage abundance on survival of tiger muskellunge. Am. Fish. Soc. Spec. Publ. 15: 151-167.

Foster, J.R. 1977. Pulsed gastric lavage: an efficient method of removing the stomach contents of live fish. Prog. Fish-Culturist 39:166-169.

Gillen, A.L., R.A. Stein and R.F. Carline. 1981. Predation by pellet-reared tiger muskellunge on minnows and bluegills in experimental systems. Trans. Am. Fish Soc. 110: 197-209.

Hanson, D.A., M.D. Staggs, S.L. Serns, L.D. Johnson, and L.M. Andrews. 1986. Survival of stocked muskellunge eggs, fry, and fingerlings in Wisconsin lakes. Am. Fish. Soc. Spec. Publ. 15:216-228.

Johnson, L.D. 1978. Evaluation of esocid stocking program in Wisconsin. Am. Fish. Soc. Spec. Pub. 11:298-301.

Klingbiel, J.H. 1986. Culture of purebred muskellunge. In: Hall, G.E. (ed). Managing Muskies. Am. Fish. Soc. Spec. Pub. 15:273-278.

Keith, W.E. 1986. A review of introduction and maintainence stocking in reservoir fisheries management. In: G.E. Hall and M.J. Van Den Avyle (eds). Reservoir fisheries management: strategies for the 80's. Res. Comm., South. Div. Am. Fish. Soc.:144-148.

Koppelman, J.B. and D.P. Philipp. 1986. Genetic applications in muskellunge management. Trans. Am. Fish. Soc. Spec. Publ. 15:111-121.

Mather, M.E. and D.H. Wahl 1989. Comparative mortality of three esocids due to stocking stressors. Can. J. Fish. Aquat. Sci. 46: 214-217.

McNeil, F.I. and E.J. Crossman. 1979. Fin clips in the evaluation of stocking programs for muskellunge (Esox masquinongy). Trans. Am. Fish. Soc. 108(4):335-343.

Savino, J.F. and R.A. Stein. 1982. Predator-prey interaction between largemouth bass and bluegills as influenced by simulated, submersed vegetation. Trans. Am. Fish. Soc. 111:255-266.

Stein, R.A., R.F. Carline, and R.S. Hayward. 1981. Largemouth bass predation on stocked tiger muskellunge. Trans. Am. Fish. Soc. 110:604-612.

Tomcko, C.M., R.A. Stein, and R.F. Carline. 1984. Predation by tiger muskellunge on bluegill: effects of predator experience, vegetation, and prey density. Trans. Am. Fish. Soc. 113: 588-594.

Van Den Avyle, M.J. and J.E. Roussel. 1980. Evaluation of a simple method for removing food items from live black bass. Progressive Fish-Culturist 42:222-223.

Wahl, D.H. and R.A. Stein 1987. Application of liquid oxytetracycline in formulated feeds to mark and treat tiger muskellunge (muskellunge x northern pike). Prog. Fish. Cult. 49: 312-314.

Wahl, D.H. and R.A. Stein. 1988. Selective predation by three esocids: the role of prey behavior and morphology. Trans. Am. Fish. Soc. 117: 142-151.

Wahl, D.H. and R.A. Stein 1989. Comparative vulnerability of three esocids to largemouth bass (Micropterus salmoides) predation. Can. J. Fish. Aquat. Sci. 46: 2095-2103.

Wahl, D.H. and R.A. Stein. 1990. Food consumption and growth by three esocids: field tests of a bioenergetics model. Trans. Am. Fish. Soc. 120:230-246.

Werner, E.E., J.F. Gilliam, D.J. Hall and G.G. Mittelbach. 1983. An experimental test of the effects of predation risk on habitat use in fish. Ecology. 64(6):1540-1548.

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Table 1. Summary of all esocid stockings in four Illinois impoundments in 1990. Total length (nearest mm) and weight (nearest 0.1g) were measured prior to each stocking (N=50). Paradise Lake and Lake George were stocked with both pellet reared (P) and minnow reared (M) fish. Lakes were stocked with tiger muskellunge (TM) or muskellunge (M).

Lake	Taxa	Stocking Date	Number of Fish	Number per Hectare	Mean Length (mm)	Mean Weight (g)
Paris (66 ha)	TM	Jun 11	2200	33	118	8.1
	TM	Jul 10	2500	38	198	48.7
	TM	Aug 13	2000	30	251	85.6
Paradise (P) (71 ha)	TM	Jul 30	1250	18	200	39.8
Paradise (M)	TM	Jul 30	1250	18	194	34.0
Pierce (66 ha)	M	Aug 21	1300	20	157	16.4
	M	Sep 17	1035	16	199	33.9
	M	Oct 23	1000	15	241	62.0
Goerge (P) (68 ha)	M	Sep 10	1175	17	189	28.9
George (M)	M	Sep 10	1175	17	193	34.0

Table 2. Schnabel population estimates and relative survival through fall 1990 of stocked esocids determined by electrofishing mark-recapture estimates. (M) designates minnow reared and (P) designates pellet reared esocids. Values in parenthesis represent total catch. Values for minnow and pellet reared tiger muskellunge were determined by the percentage of each in the total catch.

		Population Estimate		
Lake	Taxa	Point Estimate	95% C.I.	% Survival
Paris-Twin	TM (10 in)	463	182-1855	23
	TM (8 in)	(1)	--	0
	TM (4 in)	0	--	0
Pierce	MUE (10 in)	123	67-260	12
	MUE (8 in)	42	16-167	4
	MUE (6 in)	(4)	--	0
Paradise	TM (Total)	256	125-640	10
	TM (M)	212	--	17
	TM (P)	44	--	4
George	MUE (M),(P)	(1)	--	0

Table 3. Catch-per-unit-effort (CPUE) from electrofishing on successive dates after stocking for 4, 8 and 10 inch tiger muskellunge in Paris-Twin Lake. Dashes indicate dates prior to stocking of a size group. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)			CPUE (c/hr)		
		4 in	8 in	10 in	4 in	8 in	10 in
Jun 11	3.75	2	-	-	0.53	-	-
Jun 12	4.00	4	-	-	1.00	-	-
Jun 13	3.82	0	-	-	0	-	-
Jun 18	4.62	0	-	-	0.22	-	-
Jun 25	4.10	0	-	-	0	-	-
Jul 10	7.81	0	103	-	0	13.19	-
Jul 14	8.24	0	116	-	0	14.08	-
Jul 30	8.59	0	22	-	0	2.56	-
Aug 13	7.79	0	11	105	0	1.41	13.48
Aug 18	8.07	0	4	146	0	0.50	18.09
Sep 10	7.66	0	0	85	0	0	11.10
Oct 5	7.66	0	0	18	0	0	2.35
Oct 30	5.83	0	0	4	0	0	0.69
Nov 15	5.25	0	0	8	0	0	1.52

Table 4. Catch-per-unit-effort (CPUE) from electrofishing on successive dates after stocking for 6, 8 and 10 inch muskellunge in Pierce Lake, 1990. Dashes indicate dates prior to stocking of a size group. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)			CPUE (c/hr)		
		6 in	8 in	10 in	6 in	8 in	10 in
Aug 21	2.88	250	-	-	86.81	-	-
Aug 22	2.65	65	-	-	24.53	-	-
Aug 23	2.60	23	-	-	8.84	-	-
Aug 27	2.20	14	-	-	6.36	-	-
Sep 17	2.20	0	2	-	0	0.91	-
Sep 18	1.97	0	46	-	0	23.35	-
Sep 19	2.00	2	50	-	0	25.00	-
Oct 23	2.45	0	3	-	0	1.22	-
Oct 24	4.35	0	0	196	0	1.84	45.06
Nov 3	4.45	0	4	65	0	0.90	14.61
Nov 14	4.33	3	4	28	0.69	0.92	6.47
Nov 24	5.25	0	2	17	0	0.38	3.24

Table 5. Schnabel population estimates of largemouth bass (>230 mm) determined by mark-recapture in four impoundments stocked with muskellunge and tiger muskellunge, 1990.

		Population Estimate	
Lake	Taxa	Point Estimate	95% C.I.
Paris-Twin	LMB	919	829-1018
Pierce	LMB/SMB	149	104-224
Paradise	LMB	263	209-331
George	LMB	501	385-652

Table 6. Estimated numbers of esocids eaten by largemouth bass in two impoundments with tiger muskellunge (TM) and two impoundments with muskellunge (M). Values were computed by combining number of esocids per largemouth bass stomach with largemouth bass population estimates. Numbers eaten are compared for various size classes and for minnow (M) and pellet (P) reared esocids.

Lake	Taxa	Number eaten	Number stocked	Percent of total
Paradise	TM	133 (M)	1250	10.6
	TM	356 (P)	1250	28.4
George	M	307 (M)	1175	26.1
	M	633 (P)	1175	53.9
Pierce	M	99 (6")	1300	7.6
	M	173 (8")	1035	16.8
	M	0 (10")	1000	0
Paris	TM	924 (4")	2200	42.0
	TM	2253 (8")	2500	90.1
	TM	602 (10")	2000	30.1

Table 7. Catch-per-unit-effort (CPUE) from electrofishing on successive dates after stocking for minnow (M) and pellet (P) reared tiger muskellunge in Paradise Lake. Data are midpoints of one or more sample collections.

Date	Effort (hrs)	Catch (c)		CPUE (c/hr)	
		M	P	M	P
Jul 31	7.37	20	25	2.71	3.39
Aug 11	6.53	17	15	2.60	2.30
Aug 30	5.11	8	7	1.57	1.40
Sep 29	3.87	15	2	3.88	0.52
Oct 23	3.96	8	4	2.02	1.01
Nov 10	4.66	17	3	3.65	0.64
Nov 25	3.87	7	1	1.81	0.26
Dec 12	3.63	5	1	1.38	0.28
Apr 1	7.07	3	2	0.42	0.28
Apr 25	4.71	0	0	0	0
May 21	5.06	2	0	0.40	0
Jun 18	5.68	3	0	0.53	0
Jul 12	7.26	4	0	0.55	0

Table 8. Catch-per-unit-effort (CPUE) from electrofishing on successive days after stocking for minnow (M) and pellet (P) reared muskellunge in Lake George, 1990. Data are mid-points of one or more sample collections.

Date	Effort (hrs)	Catch (c)		CPUE (c/hr)	
		M	P	M	P
Sep 12	2.71	10	23	3.69	8.49
Sep 17	2.75	13	10	4.73	3.64
Sep 26	3.03	1	0	0.33	0
Oct 15	3.26	0	0	0	0
Nov 1	2.30	0	0	0	0

Table 9. Summary of habitat use and water column positioning observed during pool experiments with minnow (M) and pellet (P) reared tiger muskellunge (TM) and muskellunge (MUE). Values represent numbers of observations for all individual experiments combined.

	TM		MUE	
	M	P	M	P
Vegetation	1242	1222	703	740
Open	452	472	321	284
Low	1508	1557	963	978
High	186	137	61	46

Table 10. Average lengths and weights after stocking of 8 and 10 inch tiger muskellunge in Paris-Twin Lake from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	8 inch			10 inch		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
2	204.3	-	21	261.1	-	16
3	209.7	-	17	263.2	76.4	15
5	218.4	-	5	-	-	-
6	208.8	35.0	15	269.7	-	49
9	-	-	-	274.6	70.1	18
12	-	-	-	276.0	66.3	4
14	252.0	-	1	290.1	81.4	7
16	-	-	-	277.5	65.0	2
33	-	-	-	292.5	64.0	2

Table 11. Monthly food habits of 10 inch tiger muskellunge in Paris-Twin Lake collected from fall and spring electrofishing samples.

Date	% with food	N	Prey species composition		
			Bluegill	Largemouth bass	Unidentified
Aug	0	31	-	-	-
Sep	8	49	1	1	2
Oct	16	19	2	0	1
Nov/Dec	25	12	1	0	2
Mar	0	2	-	-	-

Table 12. Average lengths and weights after stocking of muskellunge in Pierce Lake collected from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	6 inch			8 inch			10 inch		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
2	164.9	-	14	-	-	-	237.5	55.7	20
4	-	-	-	-	-	-	238.3	55.3	47
5	184.3	24.0	4	-	-	-	233.5	50.8	4
6	-	-	-	218.5	36.2	11	239.0	53.5	13
8	-	-	-	209.3	40.0	2	-	-	-
10	193.0	21.0	1	204.4	29.2	5	-	-	-
13	216.3	42.7	3	-	-	-	-	-	-
24	-	-	-	-	-	-	238.3	47.5	4
26	-	-	-	-	-	-	230.6	40.0	5
28	-	-	-	-	-	-	246.2	47.6	5
33	-	-	-	211.5	32.0	2	262.0	62.0	2
35	194.0	24.0	1	-	-	-	-	-	-

Table 13. Monthly food habits of 6, 8 and 10 inch muskellunge in Pierce Lake collected from fall and spring electrofishing samples.

			Prey species composition					
Date	% with food	N	Gizzard shad	Shiner spp.	Brook Silverside	Largemouth Bass	Other	Unidentified
				6 inch				
Aug	6	34	0	0	0	0	1	1
Sept	50	4	1	1	0	0	0	0
Oct/Nov	25	4	1	0	0	0	0	0
				8 inch				
Oct	46	13	3	0	1	0	1	1
Nov	25	8	0	0	1	0	0	1
Mar-May	33	3	0	0	0	0	1	0
				10 inch				
Nov	10	60	1	0	1	1	0	3
Mar-May	21	14	0	2	0	0	2	1

Table 14. Average lengths and weights after stocking of minnow and pellet reared tiger muskellunge in Paradise Lake from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	Minnow			Pellet		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
2	216.4	-	5	213.7	-	6
4	224.7	48.3	8	218.3	37.3	7
8	290.3	118.7	15	257.5	74.0	2
12	340.8	201.5	8	292.0	114.8	4
14	337.3	186.8	17	337.7	178.0	3
16	324.1	179.4	7	314.0	134.0	1
18	361.0	266.4	6	336.0	186.0	1
34	390.0	352.7	3	359.0	245.0	2
43	429.3	455.0	4	-	-	-
50	467.8	550.6	5	-	-	-

Table 15. Monthly food habits of minnow and pellet reared tiger muskellunge in Paradise Lake collected from fall and spring electrofishing samples.

Date	Minnow		Pellet		Prey species composition			
	% with food	N	% with food	N	Gizzard shad	Bluegill	Largemouth bass	Unidentified
Aug	18	22	32	22	7	0	0	4
Sept	79	14	100	1	9	1	1	1
Oct	58	12	100	5	16	0	0	1
Nov	63	24	50	4	12	1	0	5
Dec	50	6	0	1	3	0	0	0
Mar/Apr	100	3	100	2	5	0	0	0
May-July	33	9	-	0	3	0	0	0

Table 16. Average lengths and weights after stocking of minnow and pellet reared muskellunge in Lake George from fall and spring electrofishing samples. Dashes indicate periods when no fish were collected or no data was available.

	Minnow			Pellet		
Week	Length (mm)	Weight (g)	N	Length (mm)	Weight (g)	N
2	200.8	-	13	200.1	-	10
3	214.0	38.0	1	-	-	-
11	-	-	-	238.0	52.0	1
30	251.7	60.5	4	-	-	-
35	254.0	60.0	1	244.5	54.0	2
38	263.5	77.0	2	-	-	-
40	-	-	-	260.0	82.0	1

Table 17. Seasonal food habits of minnow and pellet reared muskellunge in Lake George collected from fall and spring electrofishing samples.

	Minnow		Pellet		Prey species composition			
Date	% with food	N	% with food	N	Shiner spp.	Gizzard shad	Bluegill	Unidentified
Fall	21	14	9	11	1	1	1	3
Spring	43	7	67	3	5	0	0	3

Table 18. Allele frequencies of muskellunge at polymorphic loci.

Location	Loci						
	LDH-C	IDHP-2	6-PGDH-1	XDH-1	GPI-B	EST-1	EST-2
Chautaqua, NY	1- .600 2- .400	1- 1.000 2- .000	1- .375 2- .625	1- 1.000 2- .000	1- .725 2- .275	1- .000 2- 1.000	1- 1.000 2- .000
Lineville, PA	1- .675 2- .325	1- 1.000 2- .000	1- .825 2- .125	1- 1.000 2- .000	1- .800 2- .200	1- .000 2- 1.000	1- 1.000 2- .000
Union City, PA	1- .475 2- .525	1- 1.000 2- .000	1- .450 2- .550	1- 1.000 2- .000	1- .825 2- .175	1- .000 2- 1.000	1- 1.000 2- .000
Mt. Pleasant, PA	1- .450 2- .550	1- 1.000 2- .000	1- .467 2- .533	1- 1.000 2- .000	1- .800 2- .200	1- .000 2- 1.000	1- 1.000 2- .000
Morehead, KY	1- .000 2-1.000	1- 1.000 2- .000	1- .475 2- .525	1- 1.000 2- .000	1- .975 2- .025	1- .000 2- 1.000	1- 1.000 2- .000
Spirit L., IA	1- .500 2- .500	1- 1.000 2- .000	1- .786 2- .214	1- .867 2- .133	1- .300 2- .700	1- .000 2- 1.000	1- 1.000 2- .000
East Fork Hatchery, IN	1- .175 2- .825	1- 1.000 2- .000	1- .350 2- .650	1- 1.000 2- .000	1- .550 2- .450	1- .000 2- 1.000	1- 1.000 2- .000
Leech L., MN	1- .000 2-1.000	1- 1.000 2- .000	1- .733 2- .267	1- 1.000 2- .000	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000
Waterville, MN	1- .000 2-1.000	1- 1.000 2- .000	1- .867 2- .133	1- 1.000 2- .000	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000
Little Falls, MN	1- .000 2-1.000	1- 1.000 2- .000	1- .875 2- .125	1- .950 2- .050	1- .000 2- 1.000	1- .000 2- 1.000	1- 1.000 2- .000

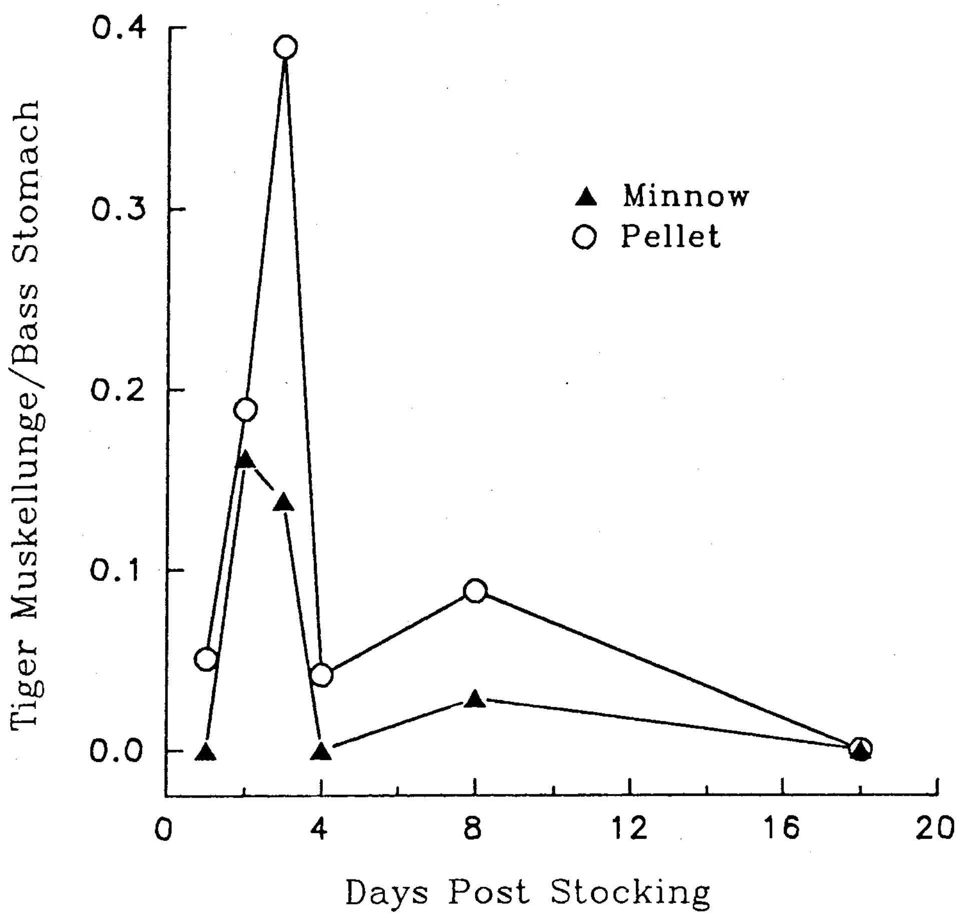

Figure 1. Numbers of tiger muskellunge recovered from largemouth bass stomachs on successive days after stocking in Paradise Lake.

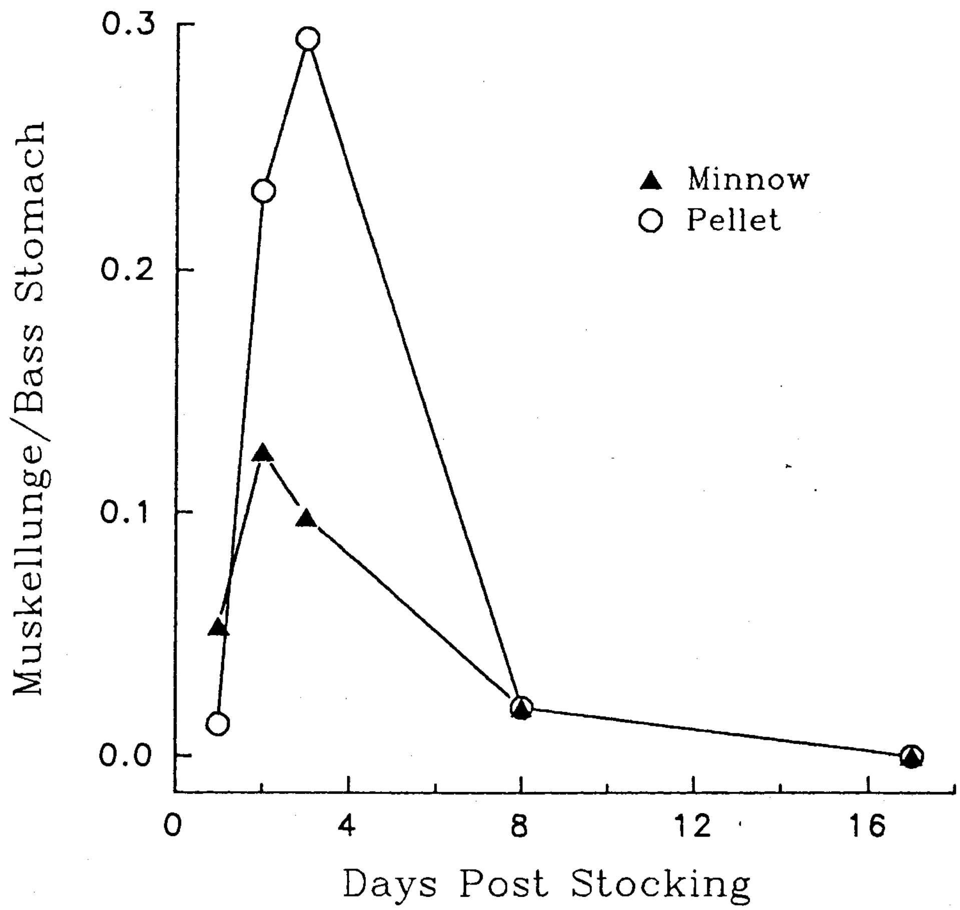

Figure 2. Numbers of muskellunge recovered from largemouth bass stomachs on successive days after stocking in Lake George.